

CONTENT OF CAROTENOIDS AND PHYSICAL PROPERTIES OF TOMATOES HARVESTED AT DIFFERENT RIPENING STAGES

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Abstract

The aim of the research was to investigate dynamics of variations of carotenoids content (lycopene and β -carotene) and physical parameters (colour and texture) in two tomato hybrids 'Admiro' and 'Kassa' and one Lithuanian tomato cultivar 'Rutuliai' during the ripening process. Investigated tomatoes were grown in the greenhouses of Lithuanian Institute of Horticulture.

During the ripening process the amount of carotenoids, especially lycopene, in fruits increased. The highest lycopene and β -carotene content was determined in red-ripe fruits of cv. 'Rutuliai', 10.44 and 1.22 mg 100g⁻¹ respectively. Lycopene content was 1.6 times higher in red-ripe fruits of 'Rutuliai' than in fruits of 'Admiro' F₁ and 2 times higher than in fruits of 'Kassa' F₁ at the same ripening stage.

The colour of tomato fruits was evaluated by the CIE L*a*b* system. The ratio of colour coordinates a* and b*, which is indicative of the red colour development in tomatoes, increased with maturity. The highest a*/b* value of 0.99 was determined in red-ripe fruits of cv. 'Rutuliai'. Strong positive correlation (r=0.86) was found between a*/b* and lycopene content in the present study.

The firmness of fruits was influenced by the degree of tomato ripeness. Turning stage tomatoes of Dutch selection 'Admiro' F₁ and 'Kassa' F₁ were the firmest, while fruit firmness of turning stage tomatoes 'Rutuliai' was less than that of Dutch selection tomato hybrids at the same ripening stage.

Key words: tomatoes, ripening, carotenoids, colour, firmness.

Introduction

Tomato is one of the most popular vegetables in the world. In Lithuania there are harvested approximately 18 000 t of tomatoes every year and about 25 000 t are consumed (Viškelis *et al.*, 2005). Tomatoes and their products provide an essential source of vitamin C, potassium, and antioxidants (primarily lycopene). Lycopene, present at high concentrations in tomatoes and tomato products, has attracted considerable attention because of epidemiological evidence that suggests this compound may provide protection against cancer and other degenerative diseases (Weisburger, 2002). Producing cultivars with big amount of lycopene has been a goal of breeders for a long time, primarily because of the increased red colour of such cultivars, but more recently because of the enhanced health benefit for humans.

The quality of fresh ripe tomatoes is influenced by growing conditions and genetic factors. The fruit ripening process results in biochemical changes that enhance fresh fruit quality, such as carotenoids accumulation and development of flavour volatiles. However, the ripening process also initiates degradative processes, such as fruit softening. The texture of the ripe fruit has significant effect on quality and influences consumer preferences, storability, shelf life, pathogen resistance and transportability.

Therefore the objective of this work was to establish the influence of fruit ripeness degree on the amount of carotenoids in tomato fruits, fruit texture and colour.

Materials and Methods

At the Laboratory of Biochemistry and Technology of the Lithuanian Institute of Horticulture there were investigated tomatoes of Lithuanian cultivar 'Rutuliai' and Dutch selection hybrids 'Admiro' and 'Kassa'. For the investigations tomatoes of four ripeness degrees (I – turning, II – pink, III – light-red and IV – red-ripe) were gathered during mass fruit yielding. Ripeness classification of tomatoes was based on external fruit colour (Saltveit, 2005). Tomato hybrids 'Admiro' and 'Kassa' were grown in the greenhouses covered with the double polymeric film ('Rovero 961'), in the mineral wool. Tomatoes of cultivar 'Rutuliai' were grown in the greenhouses covered with single stabilized film, in the soil.

The amount of carotenoids in tomatoes was established spectrophotometrically (Davies, 1976).

Tomato fruit surface colour was measured with a spectrophotometer MiniScan XE Plus (Hunter Associates Laboratory, Inc., Reston, Virginia, USA). CIEL*a*b* colour parameters were recorded as L* (lightness), a* (+ redness), and b* (+ yellowness). The chroma ($C^* = (a^{*2} + b^{*2})^{1/2}$) and hue angle ($h^\circ = \arctan(b^*/a^*)$) were also calculated (McGuire, 1992). Data were presented as the averages of the three measurements. Colour parameters were processed with program Universal Software V.4–10.

Tomato texture was measured with texture analyzer (TA.XTPlus, Stable Micro Systems, England). For the penetration of the tomato fruit 2 mm diameter flat head stainless steel cylindrical probe was used. Penetration test was started when the probe got in contact with tomato surface, and finished when the probe penetrated the tissue to a depth of 8 mm. Probe speed during penetration test was 1 mm/s. For the analysis of texture three tomatoes of each ripening degree were taken and each tomato was punctured three times around the equatorial area of the fruit. Statistical analysis was performed using Texture Analyzer software.

Results and Discussion

Ripeness degree influenced the content of carotenoids in tomato fruits. Red-ripe fruits of investigated tomatoes had the highest β -carotene and lycopene contents. Depending on cultivar or hybrid, β -carotene content in red-ripe tomatoes was 1.9–3.3 times higher comparing to the turning stage fruits (Figure 1).

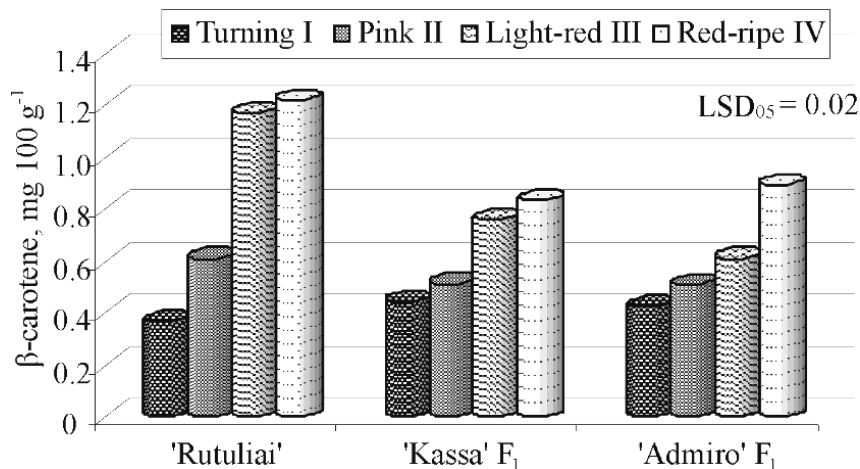


Figure 1. Content of β -carotene in tomatoes of different ripeness degree

The highest content of β -carotene was found in red-ripe fruits of cv. 'Rutuliai' (1.22 mg 100 g⁻¹). The content of β -carotene in red-ripe tomatoes of 'Admiro' F₁ and 'Kassa' F₁ was 0.89 and 0.83 mg 100 g⁻¹ respectively.

The biggest amount of lycopene was accumulated in red-ripe fruits of cv. 'Rutuliai' (10.44 mg 100g⁻¹) (Figure 2). Its content was 1.6 times higher than in fruits of 'Admiro' F₁ and 2 times higher than in fruits of 'Kassa' F₁ at the same ripening stage. The highest ratio of lycopene and β -carotene was also found in red-ripe fruits of cv. 'Rutuliai' (8.56). Though in third ripening stage (light-red) the highest lycopene/ β -carotene ratio was established in fruits of hybrid 'Admiro' F₁ (5.45).

Colour coordinate L*, characterizing fruit lightness, decreased during tomato fruit ripening (Table 1). At the beginning of ripening process these changes were not statistically significant, but when the red colour deepened, coordinate of lightness significantly decreased. The darkest were red-ripe tomatoes of cv. 'Rutuliai', 37.65.

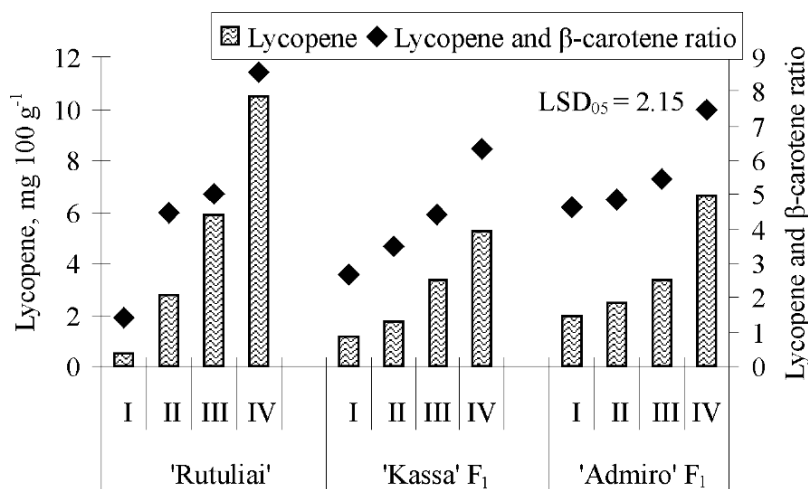


Figure 2. Amount of lycopene and lycopene/β-carotene ratio in tomato fruits of different ripeness degree

Table 1

Colour coordinates and indexes of tomatoes of different ripeness degree

Ripeness stage	L*	a*	b*	C*	h°	a*/b*
'Rutuliai'						
Turning I	46.78	5.79	26.38	27.00	77.60	0.22
Pink II	45.94	13.41	30.83	33.60	66.50	0.43
Light-red III	44.30	17.66	31.11	35.80	60.40	0.57
Red-ripe IV	37.65	21.57	21.53	30.50	44.90	0.99
'Kassa' F₁						
Turning I	46.07	3.69	21.89	22.20	80.40	0.17
Pink II	44.37	7.12	23.88	24.90	73.40	0.30
Light-red III	42.20	18.55	28.33	33.90	56.80	0.65
Red-ripe IV	39.46	19.20	25.67	32.10	53.20	0.75
'Admiro' F₁						
Turning I	48.68	2.52	20.99	21.10	83.20	0.12
Pink II	45.51	10.81	25.64	27.80	67.10	0.42
Light-red III	42.00	20.62	26.85	33.90	52.50	0.77
Red-ripe IV	40.95	21.20	25.37	33.10	50.10	0.84
LSD ₀₅	2.14	1.58	1.44	1.98	1.90	

The positive a* (redness) coordinate showed the most obvious change with maturity (Table 1). Generally, it increases as a consequence of both chlorophyll degradation and lycopene synthesis. The redness value a* during tomato fruit ripening increased from 2.52 ('Admiro' F₁) to 21.57 ('Rutuliai').

The positive b* (yellowness) value during tomato fruit ripening slightly increased from 20.99 ('Admiro' F₁) to 25.67 ('Kassa' F₁) (Table 1). Though not significantly, b* values were higher in light-red stage of the investigated tomatoes and in pink stage of 'Rutuliai' and 'Admiro' F₁ comparing to red-ripe fruits. This may be due to the fact that ζ-carotenes (pale-yellow colour) reach their highest concentration before full ripening, where lycopene (red colour) and β-

carotene (orange colour) achieve their peaks (Fraser *et al.*, 1994). The average value b^* of red-ripe tomatoes of the investigated cultivars and hybrids was 24.19.

The ratio of colour coordinates a^* and b^* , which is indicative of the red colour development in tomatoes, increased with maturity (Table 1). The highest a^*/b^* value of 0.99 was determined in red-ripe fruits of cv. 'Rutuliai'. Strong positive correlation ($r=0.86$) was found between lycopene content and a^*/b^* ratio. Additionally, strong positive correlation ($r=0.78$) was determined between lycopene content and coordinate a^* . Correlation between colour parameters and lycopene content in tomatoes was also reported by other authors (Arias *et al.*, 2000; Brandt, 2006).

Chroma C^* is an expression of the purity or saturation of a single colour. Colour purity C^* increased from turning to light-red stage of tomatoes, but in the fourth ripeness stage slightly declined (Table 1). The purest colour (the highest C^* values) was in the third stage of ripeness of all investigated tomatoes, the average – 31.9. Strong positive correlation ($r=0.78$) was found between b^* (yellowness) and colour purity C^* .

During fruit ripening of tomatoes the hue angle h° declined, because yellowness component decreased and redness – increased (Table 1). The average h° value of red-ripe tomatoes was 49.4° , it indicated that component of yellowness still had a big influence on the overall colour of tomato (90° would mean that tomato is yellow, and 0° – completely red).

Firmness of tomato fruit decreased with maturity (Figure 3). Fruits of 'Kassa' F_1 were the firmest ones, while fruits of cv. 'Rutuliai' were the softest. During fruit ripening of hybrid 'Kassa' F_1 their firmness decreased from 292.2 to 224.6 N/cm^2 . Though fruits of 'Kassa' F_1 in the fourth ripening stage (red-ripe) were almost two times firmer comparing to the fruits of 'Rutuliai' at the same ripening stage.

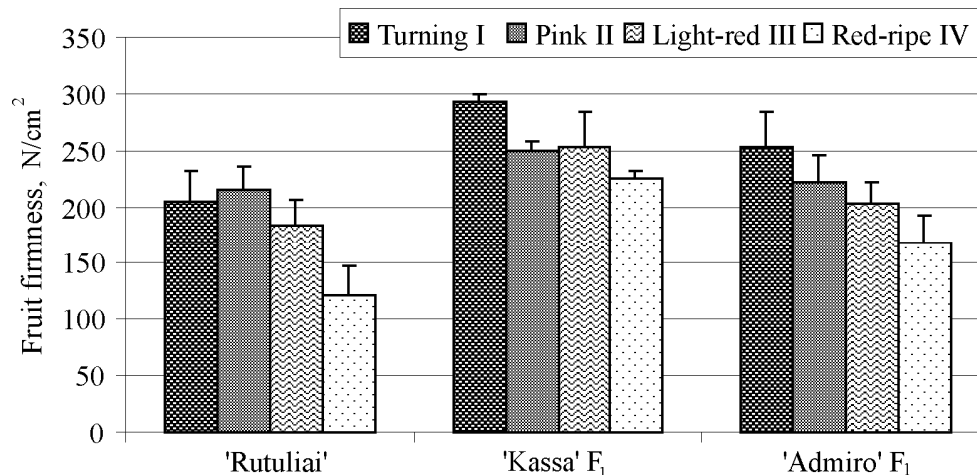


Figure 3. Firmness of tomatoes of different ripeness degree

Investigations showed strong negative correlation ($r = 0.83$) between lycopene and β -carotene ratio and tomato fruit firmness. Slightly weaker negative correlations were found between lycopene content and fruits firmness, and between β -carotene content and fruits firmness, 0.81 and 0.73 respectively. Bertin and others also investigated tomato quality changes during ripening process and reported negative correlations between β -carotene and lycopene contents and fruit firmness (Bertin *et al.*, 2001).

Conclusions

1. The highest content of lycopene and β -carotene was found in red-ripe fruits of cv. 'Rutuliai', 10.44 and 1.22 $mg\ 100\ g^{-1}$ respectively.
2. Strong positive correlation ($r = 0.86$) was found between lycopene content and a^*/b^* ratio of colour coordinates.
3. Fruits of hybrid 'Kassa' F_1 of all ripeness degrees were the firmest.

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